

Line 15 delete "inorganic";

Pg.37 Line 23 change "micronutrients" to --nutrients--;

In the Claims:

Delete Claims 1-69, 74 and 75

Add the following claims:

76. A combination seed capsule comprising:  
at least one viable seed;  
said seed acting as a core or pseudo-core of said combination  
seed capsule;  
a coating comprising dicalcium phosphate.

77. A combination seed capsule comprising:  
at least one viable seed;  
said seed acting as a core or pseudo-core of said combination  
seed capsule;  
coatings comprising a growth enhancer and material fines.

78. The combination seed capsule of claim 77 wherein said growth enhancer is  
dicalcium phosphate.

2 79. The combination seed capsule of claim 77 wherein material of said materials  
1 soil conditioning  
sludge or fly ash  
fines are comprised of industrial byproduct.

3 80. The combination seed capsule of claim 79 wherein the material is a  
fiber containing  
byproduct of a paper making process.

4 81. The combination seed capsule of claim 79 wherein the byproduct is paper  
80 3 sludge.

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~~82.~~ The combination seed capsule of claim 79 wherein the byproduct is fly ash.

~~5~~ ~~83.~~ The combination seed capsule of claim ~~79~~ wherein the material fines is comprised of municipal sewage.

~~6~~ ~~84.~~ The combination seed capsule of claim ~~79~~ wherein the material fines are comprised of sawdust ~~soil conditioning~~ ~~s~~ ~~sub~~ ~~7~~ ~~8~~ ~~9~~ ~~10~~ ~~11~~ ~~12~~ ~~13~~ ~~14~~ ~~15~~ ~~16~~ ~~17~~ ~~18~~ ~~19~~ ~~20~~ ~~21~~ ~~22~~ ~~23~~ ~~24~~ ~~25~~ ~~26~~ ~~27~~ ~~28~~ ~~29~~ ~~30~~ ~~31~~ ~~32~~ ~~33~~ ~~34~~ ~~35~~ ~~36~~ ~~37~~ ~~38~~ ~~39~~ ~~40~~ ~~41~~ ~~42~~ ~~43~~ ~~44~~ ~~45~~ ~~46~~ ~~47~~ ~~48~~ ~~49~~ ~~50~~ ~~51~~ ~~52~~ ~~53~~ ~~54~~ ~~55~~ ~~56~~ ~~57~~ ~~58~~ ~~59~~ ~~60~~ ~~61~~ ~~62~~ ~~63~~ ~~64~~ ~~65~~ ~~66~~ ~~67~~ ~~68~~ ~~69~~ ~~70~~ ~~71~~ ~~72~~ ~~73~~ ~~74~~ ~~75~~ ~~76~~ ~~77~~ ~~78~~ ~~79~~ ~~80~~ ~~81~~ ~~82~~ ~~83~~ ~~84~~ ~~85~~ ~~86~~ ~~87~~ ~~88~~ ~~89~~ ~~90~~ ~~91~~ ~~92~~ ~~93~~ ~~94~~ ~~95~~ ~~96~~ ~~97~~ ~~98~~ ~~99~~ ~~100~~ ~~101~~ ~~102~~ ~~103~~ ~~104~~ ~~105~~ ~~106~~ ~~107~~ ~~108~~ ~~109~~ ~~110~~ ~~111~~ ~~112~~ ~~113~~ ~~114~~ ~~115~~ ~~116~~ ~~117~~ ~~118~~ ~~119~~ ~~120~~ ~~121~~ ~~122~~ ~~123~~ ~~124~~ 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*A*

*13*  
92. The combination seed capsule of claim 85 wherein a binder is applied to said seed capsule.

*14*  
93. The combination seed capsule of claim 85 wherein a fertilizer is part of said *material fines*, said binder or its own layer.

*13*  
94. The combination seed capsule of claim 92 wherein said binder contains lignin.

95. A method of making seed capsules by an agglomeration operation comprising;  
spraying a binder on said seed;  
lifting and mixing said seeds with material fines.

96. The method of claim 95 wherein said seed capsules are coated with a growth enhancer.

97. The method of claim 96 wherein said growth enhancer is dicalcium phosphate.

*B*

98. The method of claim 95 wherein said material fines are comprised of industrial byproduct fines.

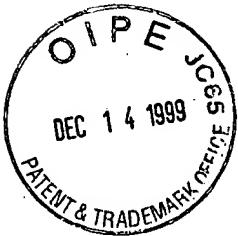
99. The method of claim 95 wherein said binder is a liquid fertilizer.

100. The method of claim 95 wherein said binder contains lignin.

Response to Office Action

Applicant has canceled the original claims in the application and has added new claims 76-100. Applicant's attorney had a telephone interview with the examiner which discussed the use of dicalcium phosphate as a seed coating, and that this was not described in the prior art presently before the Examiner.

*54*



~~R. Hatch, Jr.~~

## Granulation and Agglomeration by Fluidized Bed and Spray Drying Technology

DR. SVEND HOVMAND

NIRO ATOMIZER INC.

### INTRODUCTION

The methods to be described do not involve any mechanical agitation or compaction of the powder to be agglomerated but are agglomeration techniques derived from fluid bed dryer and spray dryer technology. With these methods, the drying and agglomeration of a product can be combined in one step in many cases. The agglomerated or granulated products from a Fluid Bed Granulator or Fluidized Spray Dryer are normally less dense and more fragile than the products agglomerated by the methods described previously in this course; however, stable and well defined agglomerates or granulates, that easily disperse in water can be produced in many applications without the addition of binder. The technology of coating particles in a fluid bed will also be described.

An overview of the techniques described here can be presented as follows:

The starting materials can influence the product characteristic. Granulation is initiated by formulation of liquid bridges. Accordingly, increasing particle surface area and absorption of water result in incomplete wetting of the surface of the particles and this will therefore result in decreasing granule size.

Granule size is directly proportional to droplet size for a given binder solution and varying the droplet size might therefore be the most suitable way of controlling the granule size.

The atomization of the liquid binder can either be performed by pressure nozzles or two fluid nozzles. Two fluid nozzles are often preferred in batch operations as they reduce the tendency to form wet agglomerates and of blockage of the nozzles. Further the position of the nozzle is an important parameter in the granulation process. Nozzles can be placed above the fluidized layer spraying downward, in the side of the fluidized layer, or at the bottom of fluidized layer near the distributor spraying upwards. Each position has advantages and disadvantages, however, no clear conclusions can be drawn from the available literature.

After granulation the granules can be dried in the fluid bed at elevated inlet gas temperatures in order to reduce the drying time.

#### C. Batch Fluid Bed Coating

Following the drying, the granules can be conveniently spray coated in the same equipment, as experience has shown that the fluidized bed is ideal for spray coating and is giving constant and reproducible coatings of the granules. Fluid

bed coating is an extreme example of fluid bed granulation. The layering mechanisms are made to dominate totally by applying very low liquid feed rates and keeping the fluidized layer dry; thus the drying rate rapid (16), (17), (18).

Coating is important in a number of industries such as pharmaceutical, agrochemical, seed treatment, food, and confectionery.

The reasons for coating are usually:

- appearance
- taste masking
- moisture protection or isolation from other ingredients
- enteric coating
- sustained release
- gastric release

The ideal fluid bed coater will ensure an even coating of each discrete granule/tablet's surface and thus ensure a perfect mix of the particles throughout the whole fluidized layer, by avoiding any dead zones in the fluid bed coater. It is crucial that each particle to be coated passes through the spray zone, preferably without being in contact with other particles and that the applied polymer is dried as rapidly as possible to prevent superficial sticking and picking off one surface to another.

The Wurster Process, Fig. 6, a spray coating process in a fluid bed where the granules are circulated up through the center while being coated, has specially being developed for coating of small and medium sized granules (10) (19).

**Briquetting, Pelletizing, Extrusion  
& Fluid Bed/Spray Granulation**  
**April 20-23, 1998**  
**Chicago, IL**

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**\*Optional Day Notes To Be Distributed**

**Optional Reading**

Koerner, Robert M. and John MacDougall. *Elements II, Briquetting and Agglomeration*.  
Hudson: Institute for Briquetting and Agglomeration.

TABLE 8-52 Size-Enlargement Methods and Applications\*

Method	Equipment	Representative applications
Pressure compaction	Piston or molding press	Plastic preforms, small machine parts from metal powders (cams, gears, gaskets), metal bearings and turnings
	Tableting press	Pharmaceuticals, catalysts, industrial chemicals, ceramics, metal powders
	Roll-type press	Clay-type minerals, potassium chloride, sodium chloride, organic compounds, metal powders, ores, charcoal, lime, magnesia, titanium sponge, phosphate rock
	Pellet mill	Pharmaceuticals, plastics, clays, carbon, charcoal, industrial chemicals, fertilizers, rubber products, animal feeds
	Screw extruder	Bauxite, plastics, rare-earth fluorides, clays, catalysts
Tumbling and mixer agglomeration	Inclined pan or disk; rotary-drum agglomerator	Fertilizers, iron ores, nonferrous ores, mineral and clay products, carbon black, various finely divided solid-waste products
	Paddle mixer; horizontal pan	Fertilizers, premixing for balling, conditioning steel-plant fines
	Powder blenders; flow-jet mixing	"Instant" foods, detergent granulation
Thermal processes	Sintering and heat hardening in travelling grate, rotary kiln, grate-kiln, shaft furnace	Ferrous and nonferrous ores, minerals, cement clinker, solid-waste products
	Drying and solidification in drum dryers, ovens, endless-belt systems	Sulfur slates, urea, ammonium nitrate, caustic, various resins, hot-melt adhesives
Spray methods	Spray dryers	Instant foods, washing powders, dyestuffs, press feeds
	Prilling towers	Urea, ammonium nitrate, resins, coal-tar pitch, etc.
	Fluidized and spouted beds	Fertilizers, clays, sulfur, nuclear and other wastes
	Flash dryers	Clays, diatomaceous earths, starch, waste by-products
Liquid systems	Immiscible-liquid wetting in various high-shear and turbine mixers	Coal fines, soot and oil removal from water
	Sol-gel process in spray column	Metal dicarbide spheroids
	Pellet flocculation in drums and stirred vessels	Waste sludge, mud and clay slurries, sewage sludge

\*Cf. Browning, *Chem. Eng.*, 74(25), 147 (1967).

# PERRY'S CHEMICAL ENGINEERS' HANDBOOK

## SI UNIT EDITION

McGraw-Hill Book Company

Prepared by a staff of specialists  
under the editorial direction of

New York  
St. Louis  
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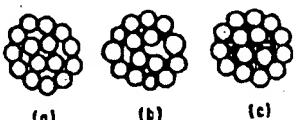
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## STRENGTH OF AGGLOMERATES 8-61

TABLE 8-52 Size-Enlargement Methods and Applications\*

Method	Equipment	Representative applications
Pressure compaction	Piston or molding press	Plastic preforms, small machine parts from metal powders (cams, gears, gaskets), metal hearings and turnings
	Tableting press	Pharmaceuticals, catalysts, industrial chemicals, ceramics, metal powders
	Roll-type press	Clay-type minerals, potassium chloride, sodium chloride, organic compounds, metal powders, ores, charcoal, lime, magnesia, titanium sponge, phosphate rock
	Pellet mill	Pharmaceuticals, plastics, clays, carbon, charcoal, industrial chemicals, fertilizers, rubber products, animal feeds
Tumbling and mixer agglomeration	Screw extruder	Baumite, plastics, rare-earth fluorides, clays, catalysts
by various	Inclined pan or disk; rotary-drum agglomerator	Fertilizers, iron ores, nonferrous ores, mineral and clay products, carbon black, various finely divided solid-waste products
	Paddle mixer; horizontal pan	Fertilizers, premixing for balling, conditioning stock-plant fines
	Powder blenders; flow-jet mixing	"Instant" foods, detergent granulation
Thermal processes	Sintering and heat hardening in traveling grate, rotary kiln, grate-kiln, shaft furnace	Ferrous and nonferrous ores, minerals, cement clinker
	Drying and solidification in drum dryers, bakers, endless-belt systems	Solid-waste products
Spray methods	Spray dryers	Instant foods, washing powders, dyes, resins, press feeds
	Prilling towers	Urea, ammonium nitrates, resins, coal-tar pitch, etc.
	Fluidized and sprayed beds	Fertilizers, clays, sulfur, nuclear and other wastes
	Flash dryers	Clays, diatomaceous earths, starch, waste by-products
Liquid systems	Immiscible-liquid wetting in various high-shear and turbine mixers	Coal fines, sand and oil removal from water
	Sol-gel process in spray column	Metal dicarboxide spheroids
	Pellet flocculation in drums and stirred vessels	Waste sludge, mud and clay slurries, sewage sludge

\*Cf. Browning, *Chem. Eng.*, 74(25), 147 (1967).FIG. 8-64 Three states of liquid content for an assembly of spherical particles. (a) Pendular state. (b) Funicular state. (c) Capillary state. [Newitt and Conway-Jones, *Trans. Inst. Chem. Eng. (London)*, 36, 422 (1958).]

**Calculation of Agglomerate Strength.** For an agglomerate composed of equal-sized spherical particles, the tensile strength  $\tau$  is (Rumpf, in Knepper (ed.), *Agglomeration*, op. cit., p. 379)

$$\tau = \frac{9}{8} \left( \frac{1 - \epsilon}{\pi X^3} \right) N F \quad (8-38)$$

where  $X$  is the particle diameter;  $F$  is the bonding force per point of contact;  $N$  is the mean coordination number, i.e., average number of points of contact between one sphere and its neighbors; and  $\epsilon$  is the volume fraction of voids in the agglomerate. Values of  $X$  and  $\epsilon$  can be obtained from a size-distribution analysis of the powder and the bulk density of the packed particles. As an approximation, the coordination number  $N$  is  $\pi/\epsilon$  (Rumpf, loc. cit.) or  $N = 2 \exp 2.4(1 - \epsilon)$  (Metzner, *Ind. Eng. Chem. Process Des. Dev.*, 3, 202 (1964)).

For mobile liquid binders in the pendular state

$$\tau = 2.8 \left( \frac{1 - \epsilon}{\epsilon} \right) \frac{\sigma}{X f(\delta)} \quad (8-39)$$

where  $\sigma$  is the surface tension of the binding liquid and  $f(\delta)$  is a function of the angle of contact [Newitt and Conway-Jones, *Trans. Inst. Chem. Eng. (London)*, 36, 422 (1958)].

If wetting is complete,  $f(\delta) = 1$ . For the capillary state

$$\tau = 8.0 \left( \frac{1 - \epsilon}{\epsilon} \right) \frac{\sigma}{X f(\delta)} \quad (8-40)$$

The tensile strength of an agglomerate in the pendular state is about one-third of that in the capillary state, while the funicular state has intermediate strengths. A decrease in particle size and porosity yields greater strength. To improve agglomerate strength, the importance of correct particle-size distribution in attaining minimum porosity should be recognized (Ridgway and Tarbuck, *Chem. Process Eng.* (February 1968)).

For the other binding mechanisms calculated values of tensile strength shown in Fig. 8-65 indicate the strength to be expected in various size-enlargement processes.

**Strength-Testing Methods.** Concepts of fracture mechanics (see subsection "Properties of Solids") are applicable to the methods of testing the strength of agglomerates.

**Compression tests.** In which agglomerates are crushed between parallel platens, are used for quick production checking. Various means of distributing the applied force uniformly over the agglomerate surface are used, including shaving off opposite sides, fitting them with hardening plastic, or covering the platen surface with compressive board.

A log-log plot of load at failure against pellet diameter for approximately spherically pellets produced under the same conditions often yields a straight line with slope approximately equal to 2. The intercept of such a plot at unit diameter yields a compressive-strength factor.

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Table 23. Review of the most important size enlargement processes and some of their typical applications

Technology	Method	Applications (typical)
Tumble agglomeration	Ball mill, pan, and cone	Iron ores, other ores, cement raw mix, fertilizers, dusts from dust collectors, fine particulate waste materials, ceramics, clay, finely divided minerals, etc.
	Mixer	Ceramic materials, fertilizers, minerals, chemicals, pharmaceuticals, foodstuffs, detergents, etc.
	Fluidized bed (gas)	Fertilizers, pharmaceutical materials, filter cakes, foodstuffs, chemicals
	Suspension (liquid)	Solids, e.g. coal, from suspensions
Induration	Shaft furnace	Iron ores, other ores, minerals, waste materials, e.g. metal-bearing dusts, etc.
	Rotary kiln	
	Straight grate	
	Grate-Kiln	
Pressure agglomeration	Calciners	
	Extrusion presses	Coals, ceramic materials, clays, polymers, plastics
	Pelleting machines	Animal feeds, rubber raw materials, catalysts, lubricants, stabilizers, pigments, polymers, clay, chemicals, pharmaceutical products, insecticides, herbicides, fungicides, etc.
	Piston presses (tableting)	Pharmaceutical products, catalysts, metal powders, ceramic materials, chemicals, pigments, plastic powders
Other agglomeration methods	Roller presses (briquetting, compacting)	Coals, coke, salts, minerals, ores, fertilizers, chemicals, metal powders, animal feeds, polymers, refractories, waste materials, metal-bearing fines, pharmaceutical products, sponge iron, etc.
	Agglomeration by heat	Ores, specifically iron ores, metal-bearing wastes and dusts, mill scale, etc.
	Spray solidification	Urea, other fertilizers, pitches, asphalt, waxes, resins, sulfur, inorganic salts, etc.
	Direct capillary action	Powders, chemicals, coal (spherical agglomeration)
Coating techniques	Alternative sources of particle movement	Finely divided particulate solids, pharmaceuticals, chemicals, food extracts (instant characteristics)
	Flocculation in gases and liquids	Pharmaceuticals, food, fertilizers and agricultural chemicals (control of release), microencapsulation of pigments, etc.
		Environmental protection, aggregation of solids in gases, flocculation of solids in liquids, selective flocculation, etc.

Table 24. Wanted and unwanted agglomeration in various processes

Product area	Wanted	Unwanted
Aggregate (+3 mm)	Briquetting, compacting + crushing and screening	
Agricultural chemicals	Tumble agglomeration (disc and drum), mixer agglomeration, briquetting, compacting + crushing and screening	Caking, bag set, build-up, flow problems, segregation due to selective agglomeration
Alumina	Granulation (tumble/pressure), calcining	Build-up, caking, flow problems
Animal feed	Pelleting, mixer agglomeration, briquetting	Caking
Carbon black	Fluid bed, mixer agglomeration, granulation by compaction	Build-up, caking, flow problems
Ceramics	Precipitation, sol-gel, spray drying and granulation, compaction + crushing and screening, tableting	Build-up, caking
(China) clay	Tumble agglomeration, extrusion	Lumping, caking
Coal	Calcinating, briquetting, tumble agglomeration, spherical agglomeration	Build-up
Detergents	Spray drying or granulation, micropelletization (drum, disc, mixer), tableting, pelleting	Caking, lumping, build-up
Dust (-0.5 mm)	Tumble agglomeration (disc, drum, fluid bed), briquetting, compacting, pelletizing (extrusion)	Build-up, caking
Fertilizers	Drum or disc granulation, compaction + crushing and screening, drop solidification	Caking, build-up, bag set
Filter cakes	Tumble agglomeration, briquetting, pelleting	Caking
Fumes (micrometer and submicrometer)	Fluid bed (with and without binder), disc and drum agglomeration	Build-up, caking, flow problems

(continued)

several types of agglomeration equipment can be identified. A description and list of equipment for each method follows:

Agitation methods are characterized by tumbling or particle-growth mixing, usually in the presence of a liquid. Available equipment includes disc pelletizers, drum pelletizers, cone pelletizers, paddle mixers, plow mixers, mixer-millers, mixer-granulators, pin mixers, coating pans, vertical mixers, cone blenders, vibrating screens, and vibrating conveyor-processors.

Pressure methods are characterized by force, as with compaction techniques. Available equipment includes briquetters, compactors, extruders, pellet mills, tabletting machines, and isostatic compaction presses.

Thermal methods are characterized by applied heat, as in sintering or fusion and melt crystallization techniques. Available equipment includes heat-hardening devices, sinter strands or grates, indurating kilns, nodulizing kilns, drying and solidifying equipment, drum dryers, belt dryers, and hot-melt drum or pan granulators.

Liquid methods are characterized by spray or fluid bed agglomeration and agglomeration from liquid media. Available equipment includes spray dryers, prilling towers, spray granulators, and immiscible liquid-wetting devices.

#### Selection Factors for Choosing an Agglomeration Method

Selecting an agglomeration process or method depends on several factors, including the kind of raw material, the type of equipment, the intended use of the end product or agglomerate, and the use of a binder or binders. In many cases, there is a trade-off or compromise not necessarily determined by one factor alone.

#### Kind of Raw Material

In some instances, the selection of a method can be entirely dependent on the raw material's size or size range and uniformity of size. For example, a raw material that is 100 percent minus 325 mesh has different process requirements than a granular-fine stream ranging from 10 mesh to 325 mesh with a uniform size distribution curve.

The material's feed moisture, bulk density, angle of repose, flow characteristics, chemical composition, and toxicity can also effect the selection process. Table 1 lists the material characteristics of typical agglomerator feed streams, as well as the agglomeration methods suitable for these materials. The table shows the influence of the condition, size, handling characteristics, and moisture content of the raw material on process selection.

It should be noted, however, that there are exceptions to these guidelines. For instance, a pasty material may have to be extruded to utilize the flowability, viscosity, and moldability characteristics of the material as it flows through the sugar and extruder dia. In another case, a relatively coarse, but dry feed-

stock with the consistency of sand may not be pelletized by agitation and pellet growth alone; pressure, induced by a double-roll briquetter, may be required to compact the particles. Other feed materials, such as wood chips, are elastic and, at times, have a rather amorphous shape and size. Pelletizing and briquetting are poor agglomeration choices for these materials. A pellet mill or pellet press that applies pressure and friction and has a certain retention time in the die is a better choice.

In many cases, it is necessary to test a representative sample of a particular material in the laboratory before one or several agglomeration methods can be selected. Regardless of whether there is a previous application history, many materials are somewhat different, even within the same species, and should be tested.

#### Type of Equipment

The selection of an agglomeration method may not involve as wide a range of possibilities and variables as the field of equipment suggests. (See Table 2) When selecting agglomeration equipment, the processes before, during, and after the actual particle size enlargement step must also be considered. The total system, including storing feed, metering, proportioning, conveying, pretreating, binder-

Table 2  
Agglomeration Capacity

Method	Maximum Capacity (tph)	Retention Time	Typical Applications
Briquetter	50	seconds	Coal, Lime, Magnesia
Compactor-Granulator	75	seconds	Fertilizer, Potash, Salt
Extruder (Auger, Screw)	30	5-10 min.	Clay, Fertilizer, Plastics
Flexible Mixer-Agglomerator	40	seconds	Chemicals, Flu Dust
Fluid Bed Granulator	30	1-10 min.	Chemicals, Fertilizer, Pharmaceuticals
Mixer-Granulator	10	> 30 min.	Ceramics, Chemicals
Nodulizing Kiln	1,000	> 30 min.	Cement, Lime, Ores
Pelletizer (Disc, Drum)	130	1-5 min.	Coal, Coal, Flu Dust
Pellet Mill	50	1-5 min.	Biomass, Plastics
Pin Mixer	25	0-5 min.	Carbon Black, Chemicals, Flu Dust
Platen Press (Ram Extruder)	5	1-10 min.	Metal chips or fines
Prill Tower	30	0-5 min.	Nitrates, Sulfur, Ores
Pugmill	300	5-10 min.	Clay, Fertilizer, Fly Ash
Sinter Strand	1,000	> 30 min.	Ferrous & Nonferrous Ores
Zig-Zag Blender	30	1-10 min.	Ceramics, Chemicals, Flu Dust

Batch time: 0.5-1 min  
Retention time = 1 sec.

adding, product handling, post-treating, screening, packaging, and shipping can influence the selection of an agglomeration device.

For example, almost all continuous agglomeration equipment requires a uniform and controllable feed, by either a volumetric or

1. height, if the actual handling of the product is reasonable, not severe, and the end use is feedstock within the plant?

The physical specifications for some agglomerates are very strict, particularly if industry practice, market standards, or competitive pressures require adherence to a code. For instance, iron ore pellets, compacted potash granules, molecular sieves, catalyst supports, and metal briquettes for furnace charge require very high product strength. On the other hand, many other agglomerates have no fixed or known standards. A realistic basis for determining the desired physical specifications reduces investing and operating costs and makes the task of the equipment supplier and test engineer much easier.

#### **Binder Use**

Binderless agglomeration, using only the natural or induced bonding forces of the particulate and the optimum densification (packing) at lowest porosity, is the most desirable and economical agglomeration method. If a liquid needs to be added to induce particle flow and compaction, water is the first choice. If binderless agglomeration or water alone cannot produce a permanent bond with high tensile strength, then additional binder materials must be added to increase the final product strength.

The method of binder classification first proposed by P.I. Waters<sup>4</sup> and further described by K.R. Komarek,<sup>5</sup> distinguishes binders by type, physicals, function, and chemical composition. Binder materials are either liquid (water, alcohol, oil, silicate, acid), solid (clay, dry starch, bentonite) or semi-solid (tar, pitch). Some binders act upon the product as film between solid particles (water, starch, silicate); others act as a matrix, filling voids between the particulates and becoming part of the dense mass of the agglomerate (tar, pitch). Those classified as chemical binders rely on the chemical reaction within the binder upon curing or heating, or between the binder and the raw material. Two binders can also be added—such as cement and water, lime and water, and lime and molasses—to produce a chemical reaction and induce bonding strength in the agglomerate.

The use of a binder is often limited by the specifications of the agglomerate. Some agglomerates can or cannot use organic binders, inorganic binders, or binders containing ash-form constituents, sulphur, or toxic materials. Cost can also limit the use of a binder. The purchase cost can make the use of an otherwise excellent binder uneconomical, or the transportation cost may be higher than the binder cost at origin.

When selecting a binder, emphasis should be placed on the proper test procedures. The selection of a binder can influence the agglomerate's post-treatment process, including

the type of equipment to be used for curing, drying, heating, and firing.<sup>6</sup> For the best results, laboratory results should be optimized and bench-tests qualified with at least one larger run in a prototype machine.

#### **Wrapping Up the Selection Process**

As this article has shown, selection of the proper agglomeration method and equipment depends on the characteristics of the raw material, the limitations of the equipment, the specifications of the desired agglomerate, and, in some instances, the choice of a binder or binders.

To help make process comparison and selection easier once this information is known, it is also useful to: study prior agglomeration applications for the same or similar raw material; review technical documentation on agglomeration methods or types of equipment made by professional societies, industry trade groups, or independent research organizations; consult industry standards on agglomerate product quality; and, compare vendor information and budget proposals. **PASS**

#### **Endnotes**

1. W.H. Engelleitner. *Selection of the Proper Agglomeration Process*, XVII, Institute for Briquetting & Agglomeration (1981).
2. W. Pietsch, "Pressure Agglomeration. The State of The Art," *Agglomeration*, 2, AIIME (1977).
3. *Ibid.*
4. P.I. Waters. *Briquette Binders. A Reappraisal*, XII, Institute for Briquetting & Agglomeration (1971).
5. K.R. Komarek, "Selecting Binders and Lubricants for Agglomeration Processes," *Chemical Engineering*, (1987).
6. J. MacDougall and V. Vellella, "Elements II: Briquetting and Agglomeration," *Introduction*, Institute for Briquetting and Agglomeration, (1983).



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